

COUNTERMEASURE THREAT EMULATOR AND METHOD

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT (1) C. RAY DUTTON, (2) LYNN A. POTTER, AND
(3) JOSEPH B. LOPES, employees of the United States Government,
citizens of the United States of America, and residents of (1)
New Bedford, County of Bristol, Commonwealth of Massachusetts,
(2) North Kingstown, County of Washington, State of Rhode Island,
and (3) Seekonk, County of Bristol, Commonwealth of
Massachusetts, have invented certain new and useful improvements
entitled as set forth above of which the following is a
specification.

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PATENT TRADEMARK OFFICE

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3 COUNTERMEASURE THREAT EMULATOR AND METHOD
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5 STATEMENT OF THE GOVERNMENT INTEREST

6 The invention described herein may be manufactured and used
7 by or for the Government of the United States of America for
8 Governmental purposes without the payment of any royalties
9 thereon or therefore.
10

11 BACKGROUND OF THE INVENTION

12 (1) Field of the Invention

13 The present invention relates generally to torpedo
14 countermeasure devices and, more specifically, to programmable
15 apparatus and methods for emulating torpedo countermeasure
16 devices.

17 (2) Description of the Prior Art

18 Torpedo countermeasure (CM) devices are used on ships and
19 submarines to confuse incoming torpedos. Therefore, a need
20 exists for testing U.S. torpedoes with respect to foreign
21 countermeasures to determine the efficacy of U.S. torpedoes when
22 confronted by countermeasures. The current methodology of
23 testing U.S. torpedoes is to use a U.S. countermeasure device

1 that is thought to be representative of a possible foreign CM
2 device, and use this U.S. countermeasure in field tests.
3 However, because prior art U.S. countermeasures may not be the
4 same as various foreign countermeasures, are highly limited in
5 the type of response which may be produced especially with
6 respect to the requirements of emulating foreign countermeasures,
7 and do not have related desirable features for this purpose as
8 discussed below, the testing may not be as complete as may be
9 desired.

10 The prior art discloses various types of training required
11 by submarines and the development of various types of acoustic
12 devices, but does not provide a solution to the above disclosed
13 problem and does not even appear to recognize this long felt
14 need. Representative patents in this area include the following:

15 U. S. Patent No. 2,887,671, issued May 19, 1959, to Burton
16 Frankel et al., discloses an invention pertaining to a sonar
17 device used in the training of sonar operators to acquaint them
18 with the characteristic sounds of a sonar ping returning from a
19 submarine. Claim 1 states: In a sonar device, an elongated hull
20 to be placed underwater and having a forward and an aft
21 transducer for receiving a sonar ping, comparing means mounted in
22 the hull for comparing the time relationship of arrival of a
23 given ping as received by the forward and aft transducers, means

1 connecting the forward and aft transducers to the comparing
2 means, signal generating means connected to the comparing means
3 for generating a signal having a characteristic which is a
4 function of the relationship, and transmitting transducer means
5 mounted on the elongated hull and connected to the signal
6 generating means for transmitting the generated signal.

7 U. S. Patent No. 5,394,376, issued Feb. 28, 1995, to
8 Laurence R. Riddle et al, discloses an apparatus for reducing
9 acoustic radiation from an enclosure containing a fluid including
10 one or more vibration sensors in communication with surfaces of
11 the enclosure. The vibration sensors feed signals corresponding
12 to detected vibrations in the surface to a radiation filter. The
13 radiation filter assigns weights to the signals and generates a
14 summation signal which is then input to a control unit, with the
15 summation signal ideally representing only those vibrations that
16 will actually radiate from the enclosure. The control unit uses
17 a reference signal and the summation signal to calculate a
18 cancellation waveform to offset the cause of the detected
19 vibrations. The cancellation signal is input to a fluid
20 displacement unit which applies pressure oscillations to the
21 fluid corresponding to the cancellation waveform.

22 U. S. Patent No. 4,184,209, issued Jan. 15, 1980, to Ralph
23 P. Crist, discloses a towed decoy system adapted to be towed from

1 a towing vessel, an electrically powered noisemaker, an
2 electrical tow cable attached to the noisemaker, a depressor
3 vane, a depressor cable connected to the depressor vane and to
4 the towing vessel, and means interconnecting the depressor cable
5 and the electrical tow cable at a point near the depressor vane,
6 the interconnecting means comprising a pair of cable grips
7 respectively attached at one end to adjacent sections of the
8 electrical tow cable and at their other ends to a snatch block
9 movably mounted on the depressor cable thereby providing slack in
10 the electrical tow cable, whereby the noisemaker is towed at a
11 depth not less than that of the point of attachment of the snatch
12 block to the depressor cable.

13 U. S. Patent No. 4,025,724, issued May 24, 1977, to Allen R.
14 Davidson, Jr. et al., discloses an array of independent sound
15 cancellation units arranged over a vibrating noise generating
16 surface. Each unit includes an arrangement of acoustic
17 transducers (sensors) positioned adjacent the surface to obtain
18 an electrical average of the local acoustic noise generated by a
19 predetermined zone of the surface. The summed average is changed
20 in phase and gain by an active filter whose output drives an
21 acoustic projector also positioned adjacent the surface and the
22 acoustic output of which sums with the original noise signal in
23 the acoustic far field, thus tending to cancel the noise. In

1 essence, each vibrating surface zone and its associated sound
2 cancellation unit tends to form an acoustic doublet. A signal
3 indicative of the projector output is used as a feedback signal,
4 with appropriate time delays, to cancel the effect of the
5 projected output signal being picked up by the unit's
6 transducers, and to cancel the effect of the output of other
7 projectors of the array.

8 U. S. Patent No. 5,033,028, issued July 16, 1991, to Douglas
9 R. Browning, discloses and describes an apparatus and method for
10 overcoming stroke limitations of moving coil reaction-mass
11 vibration dampers, by recovering armature stroke displacement.
12 The coil housing is selectively coupled or de-coupled to the
13 vibrating structure. If, when the armature reaches its travel
14 limit, sufficient damping energy has not been applied to the
15 structure, the coil-housing assembly is decoupled from the
16 structure while the armature is pulsed back to its zero
17 displacement position. The housing then is re-coupled to the
18 surface, having displaced some determinable distance from its
19 previous location relative to the surface. Additional armature
20 movement in the same direction as the previous armature stroke is
21 applied, thereby generating the needed additional damping force.
22 The resetting of the housing to its normal position vis-a-vis the
23 vibrating structure can occur at a selected time in the damping

1 force-generating cycle when reset does not impart an undesired
2 reaction to the vibrating structure. In one implementation, a
3 pair of moving-coil actuators counter-drive the vibrating
4 structure; in another, a multiplicity of additional reaction-mass
5 actuators are used.

6 U. S. Patent No. 5,341,343, issued Aug. 23, 1994, to Robert
7 L. Aske, discloses an explosive actuated acoustic device which
8 emits sound to be used in torpedo countermeasures. Numbered
9 devices are delivered over an extended area and sink through the
10 water. The devices are actuated at different times as they sink,
11 to provide sound masking over an extended period of time. The
12 devices also include safety devices which prevent premature
13 actuation from jarring or jolting and from impact with the water.

14 U. S. Patent No. 5,117,401, issued May 26, 1992, to Paul L.
15 Feintuch, discloses an active adaptive noise canceller that
16 inserts delays in the weight update logic of an adaptive filter
17 employed by the canceller to make the filter stable. It has been
18 found that there is a great deal of flexibility regarding the
19 selection of the delay values. This insensitivity permits
20 designing the delays in advance and not having to adjust them to
21 different situations as they change, thus no longer requiring a
22 training mode. The canceller dramatically reduces the amount of
23 hardware needed to perform active adaptive noise cancelling, and

1 eliminates the need for the training mode, which in some
2 applications, including automobiles, for example, can be
3 objectionable as the noise sources that are to be suppressed.

4 The above patents do not address or provide solutions to the
5 problem of testing torpedoes with respect to various types of
6 countermeasures. Consequently, it would be desirable to provide
7 an in-water device that can emulate known characteristics of CM
8 devices, both U.S. and foreign. It would be desirable for such a
9 device to be reusable, either stationary or mobile, and suitable
10 for both in-laboratory and in-water use. Moreover, it would be
11 desirable to provide a system that is totally programmable and
12 can be programmed to intercept and identify a threat waveform,
13 and then respond in a totally programmable manner, including pre-
14 programmed structured signals, broad band noise, narrow band
15 noise, echo repeater mode, swept LFM mode, or any one of several
16 possible randomly generated false alarm modes where the
17 transmission is a modified replica of the intercepted threat
18 waveform. Those skilled in the art will appreciate the present
19 invention that addresses the above and other needs and problems.

21 SUMMARY OF THE INVENTION

22 Accordingly, it is an object of the present invention to
23 provide a countermeasure threat emulator.

1 It is yet another object of the present invention to provide
2 a means for testing domestic torpedoes against foreign
3 countermeasures.

4 These and other objects, features, and advantages of the
5 present invention will become apparent from the drawings, the
6 descriptions given herein, and the appended claims.

7 In accordance with the present invention, a method is
8 provided for testing a torpedo utilizing a countermeasure threat
9 emulation system which comprises steps such as selectively
10 programming the countermeasure threat emulation system for
11 producing at least one of a plurality of foreign countermeasures
12 chosen from a database of foreign countermeasures. The
13 countermeasure threat emulation system is controlled to operate
14 at a selected depth or range of depths in the water. The
15 countermeasure threat emulation system may be stationary or
16 mobile. A torpedo is launched for testing with the
17 countermeasure threat emulation system.

18 The sounds produced by the torpedo may be analyzed with a
19 neural network within the countermeasure threat emulation system.
20 The analysis by the neural network results in an identification
21 of the torpedo. A CPU within the countermeasure threat emulation
22 system may be programmed to respond to the torpedo based on the
23 identification so derived.

1 The countermeasure threat emulation system may preferably
2 operate in duplex mode by simultaneously sending and receiving
3 acoustic signals. A digital signal processing unit within the
4 countermeasure threat emulation system may be used for
5 selectively producing a large number of different types of
6 signals including a wideband acoustic signal or a band limited
7 acoustic signal.

8 The programmable countermeasure threat emulation system
9 comprises a tubular housing suitable for launching from a
10 submarine and a power supply within the tubular housing. The
11 power supply includes controls for selectively operating remotely
12 or operating connected to an external power source. A hovering
13 system for the tubular housing is provided for controlling a
14 water depth of the tubular housing. A transmitter which may be
15 comprised of a transducer stack may be used for transmitting
16 acoustic signals. A digital signal processing unit produces
17 waveforms to be transmitted by the transmitter. A central
18 processing unit is used for storing digital information related
19 to one or more countermeasure threats and supplying the digital
20 information to the digital signal processing unit. The system
21 also comprises a database stored in a computer external to the
22 housing which contains a plurality of foreign countermeasure
23 threats. A plurality of field programmable gate arrays is

1 preferably provided for the digital signal processing unit so as
2 to make this unit programmable. A signal conditioner is operable
3 for converting a stream of digital signals into an analog signal
4 for broadcast by the transmitter.

5 In operation, the method comprises maintaining a database
6 having a plurality of foreign countermeasure threats. Data for
7 at least one of the plurality of foreign countermeasure threats
8 is downloaded into a computer within the countermeasure threat
9 emulator. The countermeasure threat emulator is launched for
10 underwater operation. An emulation of the respective foreign
11 countermeasure threat is transmitted into water through an
12 acoustic transducer. A receiver hydrophone is utilized in the
13 countermeasure threat emulator for receiving acoustic signals
14 produced by an incoming torpedo. The incoming torpedo is
15 identified from the received acoustic signals by utilizing a
16 neural network within the countermeasure threat emulator and
17 responding to the incoming threat based on the identification and
18 a preprogrammed response for the identification.

19 20 BRIEF DESCRIPTION OF THE DRAWINGS

21 A more complete understanding of the invention and many of
22 the attendant advantages thereto will be readily appreciated as
23 the same becomes better understood by reference to the following

1 detailed description when considered in conjunction with the
2 accompanying drawings wherein corresponding reference characters
3 indicate corresponding parts throughout the several views of the
4 drawings and wherein:

5 FIG. 1 is a schematic representation of a countermeasure
6 unit in accord with the present invention; and

7 FIG. 2 is a schematic block diagram of countermeasure
8 electronics for the countermeasure unit of FIG. 1.

9
10 BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS

11 Referring now to the drawings and, more particularly, to
12 FIG. 1 there is shown a countermeasure threat emulator 10 in
13 accord with the present invention. CM threat emulator 10 may be
14 provided within a six inch CM housing or other size housing 12 so
15 as to preferably be launchable/retrievable from a torpedo tube.
16 CM threat emulator 10 includes countermeasure electronics unit 14
17 discussed hereinafter and shown in block diagram form in FIG. 2.
18 CM threat emulator 10 is provided with hovering system 16 for
19 controlling water depth, which may also be used in making CM
20 threat emulator 10 mobile. While CM threat emulator 10 is
21 preferably reuseable, one embodiment of CM threat emulator 10 may
22 be made low enough in cost so as to be expendable by using, for
23 instance, mostly salvaged components of existing countermeasure

1 devices. For remote operation, power source 18 may be used
2 although when tethered to surface controls, CM threat emulator 10
3 can be operated using external power from external control 20.
4 Power control electronics 19 can be provided to perform such
5 functions as switching between power supply sources, recharging,
6 and the like. Power supply 18 and/or power from external control
7 20 may be used to provide power to DC/DC converter 21 (see FIG.
8 2) for powering CM electronic unit 14.

9 Preferably, CM electronic unit 14 utilizes commercial off
10 the shelf technology wherever possible. CM emulator electronics
11 14 may include up to four digital signal processors (DSP) 22,
12 such as the Texas Instruments TMS320C40. In a preferred
13 embodiment, the main software runs on four DSP processors. DSP
14 processing unit 22 is interconnected with transducer interface 26
15 by high speed bus 24. Interface 26 preferably includes at least
16 four analog channels in and four analog channels out. As well,
17 interface 26 preferably includes at least sixteen channels of
18 high speed digital input/output (TTL) for cooperation with high
19 speed bus 24 and for use by signal conditioner and power
20 amplifier 27. The analog channels may also be used in
21 conjunction with signal conditioner and power amplifier 27.
22 Signal conditioner/power amplifier 27 may be used to convert
23 digital streams of TTL signals to analog sinusoidal waves for use

1 by a transducer stack such as transducer stack 30. Signal
2 conditioner 27 therefore connects to one of several possible
3 transducer stacks, or transmitters 30, such as an ADC MK2 array,
4 an ADC MK3 array, or a BQR-7 spherical array.

5 Signal conditioner 27 also preferably connects to a receive
6 hydrophone 28. Receive hydrophone 28 will serve to collect in-
7 water data of incoming torpedo threats from the view-point of the
8 countermeasure hydrophones. The data so collected and stored by
9 CPU 34 will be used to enhance simulation and modeling efforts,
10 and then verify the mathematics used in development of the other
11 countermeasure techniques. Thus, the memory of CPU 34 may be
12 downloaded into computer 32 for such analysis.

13 Electronics unit 14 including CPU 34 are totally
14 programmable and can be programmed by external computer 32, such
15 as a weapons control panel or laptop computer, to intercept and
16 identify a threat waveform by means discussed hereinafter, and
17 then respond in a totally programmable manner, including pre-
18 programmed structured signals, broad band noise, narrow band
19 noise, echo repeater mode, swept LFM mode, or any one of several
20 possible randomly generated false alarm modes (where the
21 transmission is a modified replica of the intercepted threat
22 waveform).

1 In order for CM threat emulator 10 to be programmable, CM
2 electronics unit 14 is therefore designed to be programmable. CM
3 electronics unit 14 may be programmed to respond in any arbitrary
4 fashion or with specific characteristics. CM electronics unit
5 14 can be programmed via an alterable and updateable database 35
6 to emulate a plurality of foreign CM waveforms and signal types
7 as indicated by 36, 38, and 40. CM threat emulator 10 may also
8 be used to imitate other countermeasure devices 41 such as
9 various existing domestic countermeasure devices. The device
10 requirements for the CM database 35 come from the MK2, MK3, and
11 MK4 system specification documents, from available foreign
12 documents, and from efforts to develop operating characteristics
13 of rest of the world CM devices, and the like. Thus, the
14 information for CM database 35 has been obtained, will be updated
15 in the future, and is preferably maintained in one form as
16 downloadable CM database 35 for use by CPU 34.

17 As indicated above, CM threat emulator 10 can be made to
18 emulate mobile threat countermeasures as well as stationary ones.

19 Preferably, CM threat emulator 10 can operate in full duplex
20 mode, receiving transmissions from receive hydrophone 28 while
21 broadcasting from transmitters 30. Depending on the selection of
22 type of countermeasure to be emulated, CM threat emulator 10 can
23

1 be programmed to operate in either a wideband or band limited
2 manner.

3 The processors provided in DSP processing unit 22 are
4 preferably in a format that can be used to permit a wide array of
5 different types of signals to be processed. Preferably, neural
6 network 42, such as a Ni-1000 Recognition Accelerator Chip from
7 Nestor and Intel is provided for pattern recognition of incoming
8 threats so as to identify the particular threat. Neural network
9 based processor 42 will be used for incorporation of research
10 into classification of incoming torpedoes based on pattern
11 recognition of acoustic signatures processed with advanced time
12 frequency distribution and wavelet algorithms.

13 DSP processing unit 22 preferably includes field
14 programmable gate arrays (FPGA) and flash memories for at least
15 two purposes. One use will be in digital "glue logic" functions
16 for consolidation of space and functional enhancement. Secondly,
17 the FPGA's and flash memories may be used to provide
18 reconfigurable DSP logic. FPGA technology can be used for
19 construction of high speed digital signal processing logic.
20 Additionally, the FPGA's are dynamically programmable, so the DSP
21 processing elements can be re configured based on changing
22 tactical information (for example, the FPGA's could be designed
23 as a tunable digital filter, or as an iterative bank of filters),

1 or can possibly be reprogrammed by an advanced CM shipboard
2 launcher designed to use such flexibility.

3 The programmability of CM threat emulator 10 makes the
4 system virtual, giving the CM threat emulator 10 the ability to
5 emulate any CM device under software control. The bulk of the
6 processing and control software preferably running under the
7 Texas Instrument's TMS320C40 digital signal processing chips may
8 be developed using the Pegasus Parallel Processing Design
9 Environment developed by Jovian Systems, Inc. The parallel C40
10 digital signal processor software development system may be used
11 to auto-generate C code suitable for use on a network of multiple
12 interconnect C40 modules using a graphical icon based
13 environment. The final product is multi-threaded and multi-
14 tasking executable code that can be easily distributed over the
15 multiple modules via the C40's high speed communication ports.

16 In summary, a relatively low cost CM threat emulator 10 may
17 serve as a test platform for in-water testing of new concepts and
18 technology for next generation CM device development and as a low
19 cost test vehicle for U.S. Torpedo Programs requiring foreign CM
20 device acoustic signatures. The present invention takes
21 advantage of presently available information about foreign and
22 domestic torpedo countermeasure devices to provide the technology
23 for providing a virtual countermeasure concept. CM threat

1 emulator 10 is suitable for in-water use, where it will be
2 designed to be deployed from both submarine and ship platforms,
3 serving a dual role as a developmental platform for testing new
4 concepts and technology. CM threat emulator 10 also acts as a
5 low cost test vehicle for U.S. Torpedo Programs requiring foreign
6 CM device acoustical signatures for high fidelity testing of U.S.
7 Torpedoes.

8 Numerous variations of the above method are possible, some
9 of which have already been described. Therefore, it will be
10 understood that many additional changes in the details,
11 materials, steps and arrangement of parts, which have been herein
12 described and illustrated in order to explain the nature of the
13 invention, may be made by those skilled in the art within the
14 principle and scope of the invention as expressed in the appended
15 claims.